MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

Trimester 2, 2015/2016

EPH7026 – OPTICAL MATERIALS

5 March 2016
2:30 pm – 5:30 pm
(3 Hours)

INSTRUCTIONS TO STUDENT

1. This Question paper consists of 5 pages including cover page with 4 Questions only.

2. Attempt **ALL** FOUR questions. All questions carry equal marks and the distribution of the marks for each question is given.

3. Please print all your answers in the answer Booklet provided.

Question 1

(a) The interaction of electromagnetic waves with materials often exert forces on the charges by the electric field of the waves, and also motion of charges by the magnetic field of the waves.

(i) In response to the electromagnetic wave, briefly explain the behaviour of these charges. [2 marks]

(ii) With the aid of a diagram, illustrate the frequency dependence of polarization. [6 marks]

(iii) What is dispersion for an optical material? [2 marks]

(b) The following relationship:

$$k^2 = \mu\varepsilon\omega^2 + i\mu\sigma\omega$$

describes the wave propagation characteristic in a non-zero conductivity (σ) materials by Maxwell equation, where μ = permeability, ω = wave frequency, ε = permittivity, and i defines the imaginary term of propagation constant k. If the propagation constant is a complex number given by $k = k_1 + ik_2$, obtain the expression(s) considering

(i) k for a non-conductor and far from resonant polarization; [2 marks]

(ii) k_1 and k_2 for a weak conductor, [6 marks]

where the refractive index is given by $n = (\mu\varepsilon/\mu_o\varepsilon_o)^{1/2}$.

(c) (i) Define what are isometric crystals? [1 mark]

(ii) With the aid of a simple diagram, briefly describe the refractive indices of anisotropic crystals as a function of temperature. [3 marks]

(iii) With the aid of a geometrical ray diagram, explain the birefringence of light in a anisotropic crystal. [3 marks]

Continued--

Question 2

(a) With reference to Figure Q2 below, a thin film has been deposited on a substrate and the reflectance is given by

$$R = [(n_o n_2 - n_1^2)/(n_o n_2 + n_1^2)]^2$$

where n_o, n_1 and n_2 are, respectively, the refractive index of air, thin film and the substrate.

(i) Explain interference of the reflected rays. [2 marks]

(ii) Obtain n_2 in term of n_o and n_1 for simple anti-reflection. [4 marks]

(iii) What should the thickness of thin film be for anti-reflection coating? [2 marks]

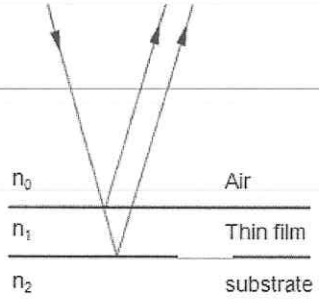

Figure Q2

(b) (i) Solar cells are often coated with transparent thin film, such as silicon monoxide (SiO, n = 1.45), in order to minimize reflective loses from the surface. A silicon solar cell (n = 3.5) is coated with a thin film of SiO, determine the minimum thickness that will produce the least reflection at 550 nm of light wavelength. Comment on the effectiveness of the above anti-reflection coating with SiO. [3+2 marks]

(ii) The reflectance R for a substrate (n_s) with double-layer (n_1 and n_2), quarter-wave coating is given by:

$$R = [(n_o n_2^2 - n_s n_1^2)/(n_o n_2^2 - n_s n_1^2)]^2$$

for normal incidence and n_o is refractive index of air. Obtain an expression for zero reflectance, and calculate the ratio of n_2/n_1 if $n_s = 1.52$ for glass as substrate. [4 marks]

(c) (i) Compare the reflectance of metallic mirrors using aluminium, silver and gold coatings. [5 marks]

(ii) With the aid of a diagram, briefly explain Fabry-Pérot etalon and its application. [3 marks]

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Question 3

(a) (i) With the aid of suitable diagrams, illustrate three types of fiber geometry, index profile, light path and its effect on the input light pulse at the end of long-distance propagation.

[6 marks]

(ii) Name three mechanisms which largely contribute to the minimum intrinsic loss of optical fiber. Plot the attenuation caused by these three loss mechanisms as a function of wavelength. [4 marks]

(b) (i) Suppose an optical fiber (core index=1.465, cladding index=1.460) is being used at $\lambda = 1.25$ μm. Determine the diameter for single-mode performance and the number of propagation modes if the fibre diameter is $d = 50$ μm.

[3 marks]

(ii) Briefly explain what is the modal distortion, and give the major causes. Calculate the modal distortion if the core index is 1.46 and cladding index is 1.45.

[1+3+2 marks]

(c) Besides optical fibre communication, specialty fibers such as rare-earth doped fibers for laser and amplifier applications have been fabricated using the direct nanoparticle deposition (DND) technology.

(i)List the advantages of DND technology. [2 marks]
(ii)With the aid of a diagram, briefly describe a fabrication method for enabling DND of Ytterbium-doped fiber. [4 marks]

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Question 4

(a) (i)Briefly explain what is optical nonlinear phenomena of a medium? [2 marks]

(ii)The polarization (P) of a linear medium by an electric field (**E**) is given by

$$\mathbf{P} = \varepsilon_0 \chi \mathbf{E}$$

where ε_0 = permittivity of free space, and χ = susceptibility. Under the intense, coherent light intensity, if the optical medium behaves optically nonlinearly, what should be the form for χ and nonlinear polarization $\mathbf{P}_{NL}$. [2 marks]

(iii)Estimate the electric field amplitude and irradiance that would cause the second-order nonlinear contribution to the polarization to be 1% of the linear contribution in KDP crystal (KH_2PO_4). KDP has a refractive index of 1.5 and a second-order nonlinear susceptibility $\chi_2 = 10^{-12}$ m/V. [6 marks]

(b) (i)Briefly explain what are electro-optic effects, and name two such effect. [4 marks]

(ii)The half-wave voltage of a Pockel cell is given by

$$V_{HW} = \lambda_o / (2rn_o^3)$$

where λ_o = optical wavelength in vacuum, r = linear electro-optic coefficient, and n_o = refractive index of the medium. Suppose the Pockel cell is made from a KD*P crystal of 1-cm thickness, λ_o = 633 nm, r = 24.1×10^{12} m/V, and n_o = 1.51, calculate the half-wave voltage. [2 marks]

(iii)With aid of diagram, briefly explain how a Pockel cell is used to enable the pulsed mode operation of a Nd:YAG laser. [4 marks]

(c) (i)The coherent length of a nonlinear crystal is given by

$$L_C = \pi / \Delta k$$

where k is the wave vector. Derive an expression of L_C in term of refractive-index difference (Δn) between the fundamental wave and second-harmonic wave. [2 marks]

(ii) If an intense light with wavelength given by λ_o = 0.8 μm is incident on a crystal with refractive index for fundamental wave is 1.5019, while that of second harmonic is 1.482, calculate the coherent length. Comment on the coherent length obtained. [2+1 marks]

End of Paper